

ANATOONS

A N A T O M Y M A D E S I M P L E

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RESPIRATORY SYSTEM 2

Part 2

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The Trachea

- The trachea is a fibromuscular tube 10-12 cm long.
- It is kept patent by the presence of C-shaped bars (rings) of hyaline cartilage embedded in its wall.
- It is not quite cylindrical but is flattened posteriorly, So that in transverse section its lumen is like a letter D

Length

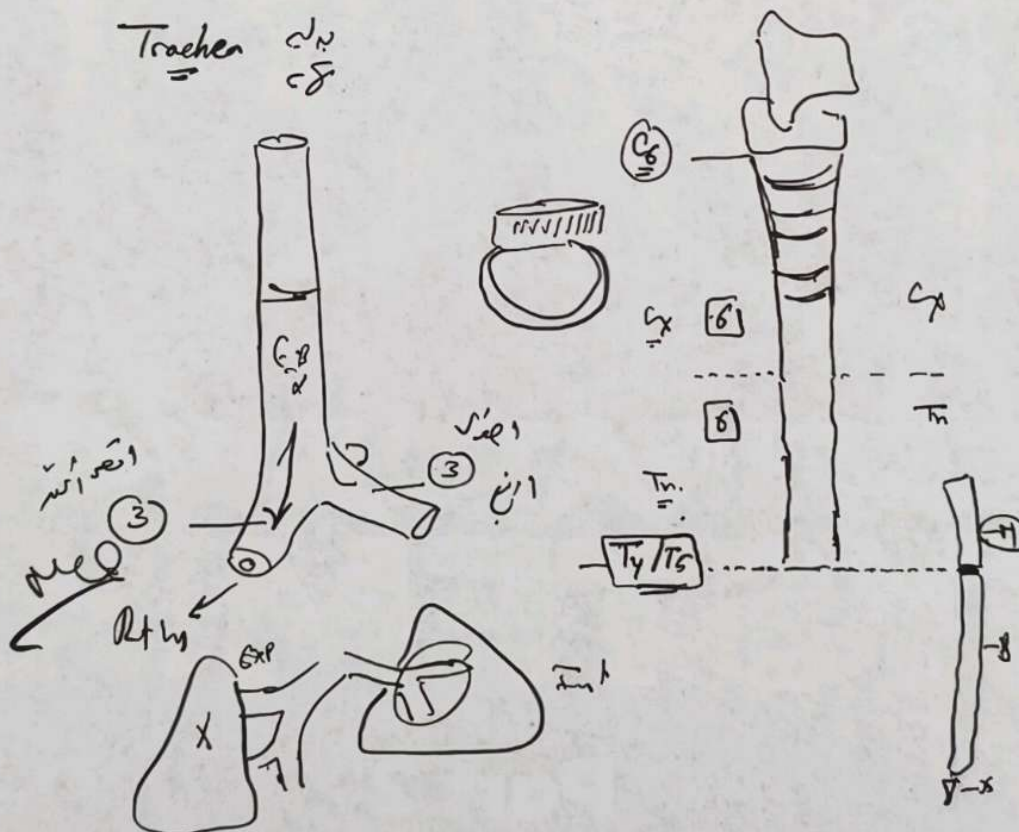
- is about 10-12 cm.

Beginning

- It begins in the neck as a continuation of the larynx at the level of the sixth cervical vertebra.

Termination

- In the thorax, the trachea ends at the level of the sternal angle by dividing into the right and left main bronchi.
- The tracheal bifurcation (carina) is usually a little to the right of the median plane.
- During deep inspiration, the bifurcation of the trachea may descend to T6 vertebra.



Relations of the trachea

Cervical part of the trachea:

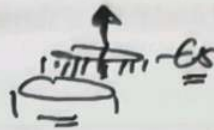
Anteriorly:

- Thyroid isthmus covers 2, 3 & 4 tracheal rings.
- Sternohyoid & sternothyroid muscles.
- Inferior thyroid veins descend over its lower part.



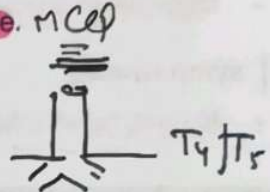
On either side:

- Lobe of thyroid gland
- CCA - C. Subcl.
- Brachiocephalic artery on the right side.



Posteriorly:

- Esophagus
- Recurrent laryngeal nerve ascending in the trachea-esophageal groove.



Thoracic part of the trachea:

= Sup. Mediastinum

Anteriorly:

- Deep part of cardiac plexus and lymph nodes on the tracheal bifurcation.
- Arch of aorta and beginning of brachiocephalic and left common carotid arteries.
- Inferior thyroid and left brachiocephalic veins.
- Remnants of thymus.
- Origin of sternohyoid and sternothyroid muscles.
- Manubrium sterni.

On the right side:

- Right vagus
- Arch of azygos.
- Right brachiocephalic vein and SVC.
- Right pleura and lung.



On the left side:

- Arch of aorta.
- Left common carotid & left subclavian artery.
- Left recurrent laryngeal nerve: is at first situated between the trachea and arch of aorta, then in the groove between the trachea and the esophagus.

Posteriorly:

- The esophagus separating it from the vertebral column.

Supply of trachea**Arterial**

- Inferior thyroid artery ✓
- bronchial arteries. ✓

Venous drainage

- Left brachiocephalic veins.

Lymphatic drainage:

- Pretracheal and paratracheal lymph nodes.

Nerve supply:**Parasympathetic**

- from the vagi and recurrent laryngeal nerves

sympathetic

- from sympathetic trunks.

The bronchi

- The right and left principal bronchi start at the tracheal bifurcation opposite the lower border of T4 vertebra.
- Each bronchus passes obliquely lying in the middle mediastinum to enter the hilum of the corresponding lung and divides into lobar bronchi which give rise to segmental bronchi.

N.B.

- A foreign body which may enter the trachea, will pass usually in the right bronchus because it is wider and more in line with the trachea.

	Right bronchus	Left bronchus
Length	Short (2.5 cm)	Long (5 cm)
Diameter	Wide	Narrow
Course	Vertical, in line with Trachea	Oblique or horizontal
Division into lobar Bronchi	Extra pulmonary	Intrapulmonary

↓
 Foreign Body
 ↓
 Rt. Bronchus
 not left

Joints of the Thoracic Wall

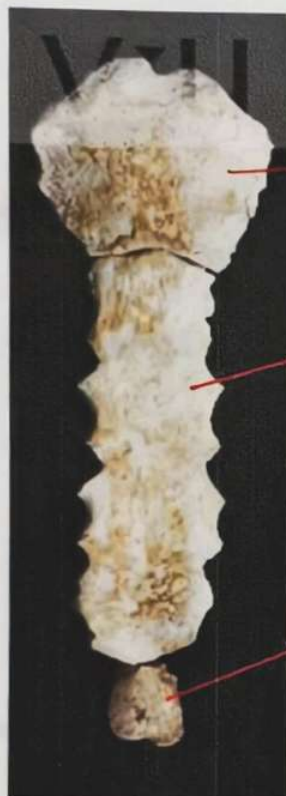
joints of The sternum

The manubriosternal joint

- a **cartilaginous joint** between the **manubrium** and the **body** of the sternum. $\begin{matrix} T_4/T_5 \\ \text{2nd } \underline{C.C} \end{matrix}$
- A small amount of angular movement is possible during respiration.

The xiphisternal joint

- a **cartilaginous joint** between the **xiphoid process** and the **body** of the sternum. $\begin{matrix} T_9/T_{10} \\ \text{2nd } \underline{C.C} \end{matrix}$
- The xiphoid process usually fuses with the body of the sternum during middle age.



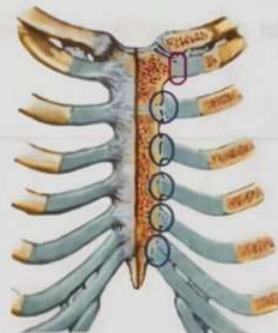
Manubrium

Body

Xiphoid

stand Angle

- 2nd Costal Cartilage
- Disc between T_4/T_5



Costovertebral joints:

Joints of the heads of the ribs:

The head of each rib from the 2nd to the 9th ribs

- Articulates by means of a synovial joint with the costal facet of the corresponding vertebral body and that of the vertebra above it (e.g. the head of the 6th rib articulates with the superior part of the body of T6 the inferior part of T5 and the intervertebral disc between these vertebrae).

The 1st rib and the 10th, 11th, and 12th ribs

- Have a single synovial joint with their corresponding vertebral body. *Radiate lig.*
- There is a strong intra-articular ligament that connects the head to the intervertebral disc.
- Only slight gliding movements occur at the demifacets, pivoting around the intra-articular ligament of the joints of the heads of ribs.

Costotransverse joints (joints of the tubercles of the ribs):

- The tubercle of a rib articulates by means of a synovial joint with the transverse process of the corresponding vertebra.
- This joint is absent on the 11th and 12th ribs

Supporting ligaments:

Costotransverse ligament

- passing from the neck of the rib to the transverse process

Lateral costotransverse ligament

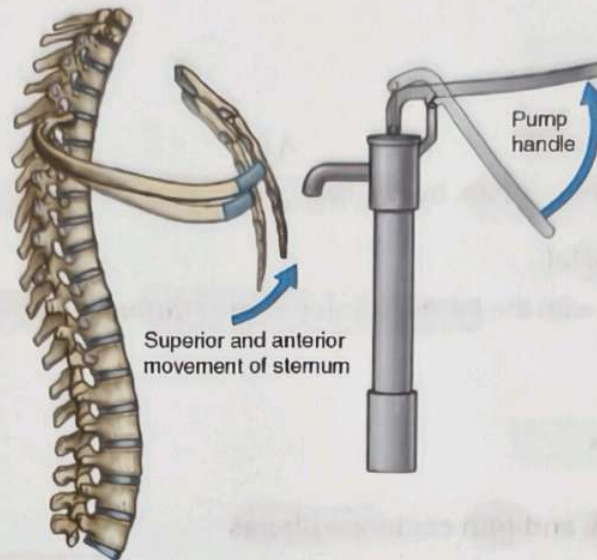
- passing from the tubercle of the rib to the tip of the transverse process

Superior costotransverse ligament

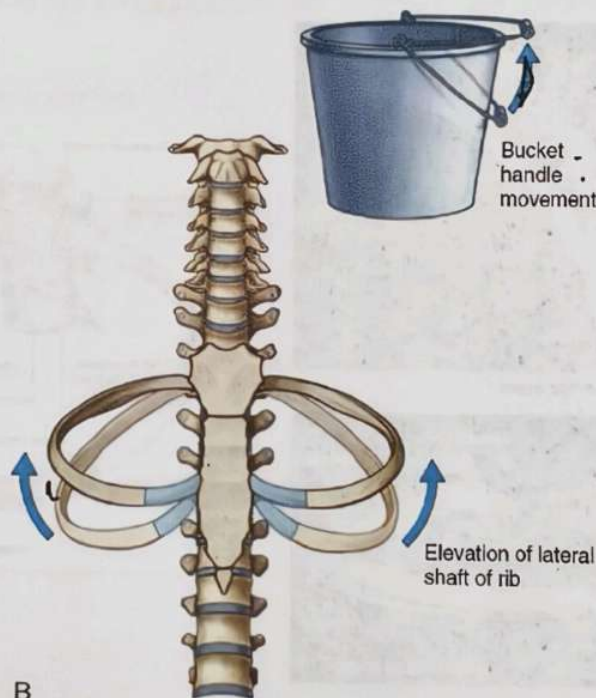
- is a broad band that joins the crest of the neck of the rib to the transverse process superior to it

Rotation movement

- Occurs around a transverse axis that traverses the head and neck of the **upper 6 ribs**
- this results in elevation and depression movements of the sternal ends of the ribs and the sternum causing the **pump-handle** movement.

**Gliding movement**

- Of the joints of the 7th -10th ribs result in elevation and depression of the lateral-most portions of these rib in the transverse plane causing the **bucket-handle** movement



B

Costochondral joints (joints of The ribs and costal cartilages)

- These joints are **cartilaginous joints**. $\Delta \gamma$.
- No movement normally occurs at these joints.

Sternocostal joints**The first costal cartilages** $\Delta \gamma$

- articulate with the **manubrium**, by **cartilaginous joints** that **permit No movement**.

The 2nd to the 7th costal

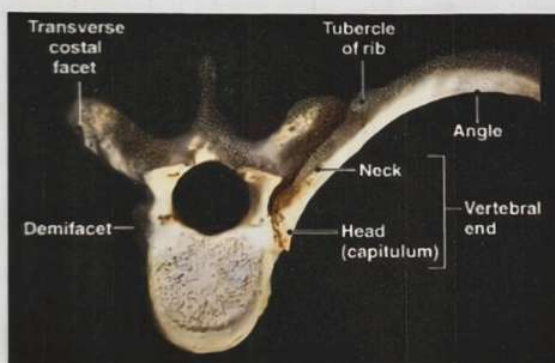
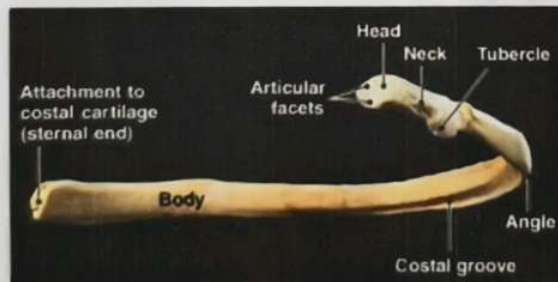
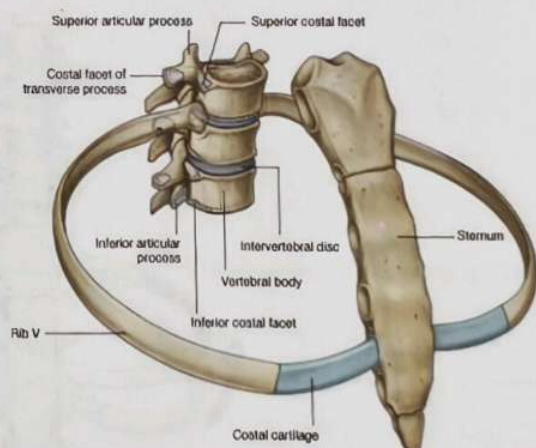
- cartilages articulate with the **lateral border of the sternum** by **synovial joints**.

Interchondral joints**The 6th, 7th, 8th, 9th, and 10th costal cartilages**

- articulate with one another along their borders by small **synovial joints**.

The cartilages of the 11th and 12th ribs

- are **embedded in the abdominal musculature**.

**(a) Superior view****(b) Posterior view**



The intercostal muscles

Connect adjacent ribs and are arranged into 3 layers from out inward:

1. External intercostal muscles:

Extent:

- from the tubercle of the ribs posteriorly to the costochondral junction anteriorly where it is replaced by an aponeurosis, the anterior (external) intercostal membrane.

Attachments:

- Each muscle passes from the lower border of one rib to the upper border of the rib below.

Direction of fibers:

- downwards & forwards (as one putting his hand in his pocket).



2. Internal intercostal muscles:

Forms the intermediate layer:

Extent:

- from the sternum in front to the angle of the rib behind where each is replaced by internal (posterior) intercostal membrane.

Attachments:

- Each muscle descends from the floor of the costal groove of one rib to the upper border of the rib below.

Direction of fibers:

- downwards, backwards i.e. at right angles to those of the external intercostal muscle.

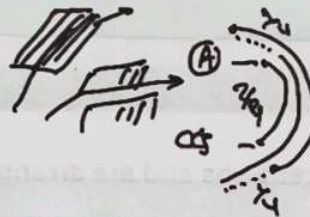


3. Innermost intercostal muscles:

Forms the deepest layer:

It is considered to be the deeper part of the internal intercostal muscle which is split off by the intercostal vessels & nerves.

Int / In



Extent:

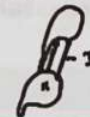
- occupy the middle 2/4 of the intercostal spaces.

Attachments:

- Each muscle is attached to internal aspects of two adjoining ribs (from the upper border of the costal groove of one rib to the upper border of the rib below).

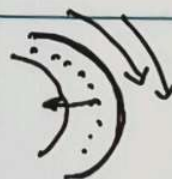
Direction of fibers:

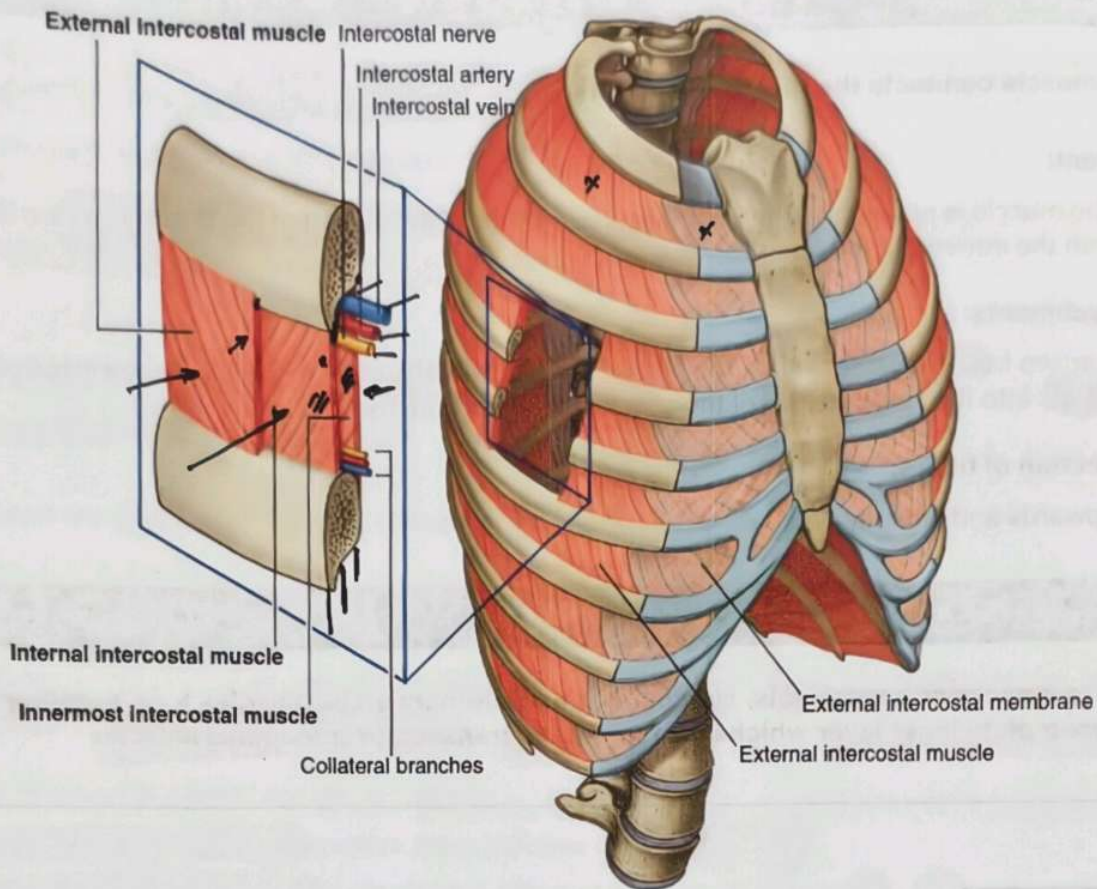
- As internal intercostal; actually it is considered to be a part of the internal intercostal which is split off by the intercostal nerves and vessels.



Note

- The innermost intercostal muscles are related internally to the endothoracic fascia and parietal pleura and externally to intercostal nerves and vessels.





Subcostal Muscles (Subcostales):

These muscles **cross 2-3 ribs** between their attachments.

Extent:

- They are well developed only in the **lower and posterior part of the thorax** lying near the angles of the ribs.

Attachments:

- like those of the **internal intercostal muscles**.

Direction of fibers: ✕

- As internal intercostal; actually it is considered to be a part of the **internal intercostal** which is split off by the intercostal nerves and vessels.

Note

- **The subcostales, like innermost intercostals** is related internally to **fascia (endothoracic fascia)** and **parietal pleura** and externally to the **intercostal nerves and vessels**.

Transversus Thoracis (Sternocostalis):

This muscle connects the ribs to the sternum.

Extent:

- The muscle is present on the internal surface of the anterior part of the thoracic wall in line with the innermost intercostal.

Attachments:

- it arises from the lower half of the posterior surface of the body of sternum to be inserted by 5 slips into the lower border of the costal cartilages from the 2nd to the 6th.

Direction of fibers:

- upwards and laterally.

Note

- The innermost intercostals, subcostales and sternocostalis muscles form together an incomplete inner layer which corresponds to transversus abdominis muscle.

Nerve supply of muscles of The Thorax:

- All the above mentioned muscles are supplied by the adjacent intercostal nerves.

Action of muscles of The Thorax:**The external intercostal muscles**

- are most active in inspiration (elevators of the ribs).

The internal and innermost intercostal muscles

- are most active in expiration (depressors of the ribs).

Subcostales muscle:

- probably depresses the ribs.

Transversus thoracis:

- draws down the costal cartilages to which it is attached.



Notes:

- The **role of these muscles** in **producing movement** of the ribs appears to be related mainly to **forced respiration**.
- The **diaphragm** is the **primary muscle of inspiration**.
- The **intercostal muscles** support the contents of the **intercostal spaces** preventing them from being drawn in during inspiration or bulged out during expiration.

Intercostal Nerves

- There are **12 pairs of thoracic** spinal nerves.
- The **ventral rami** of these nerves form the **intercostal nerves** (the upper eleven) and the subcostal nerve (the 12th).
- Each **intercostal nerve** runs in the **corresponding intercostal space** while the **subcostal nerve** runs below the last rib.

The intercostal nerves are classified as:

- **Typical intercostal nerves** which have a similar course (T3 - T6).
- **Atypical intercostal nerves** which have different courses (T1, T2 and T7 - T11).

1. Typical intercostal nerves (T3-T6):

Course

- Each nerve emerges from the corresponding **intervertebral foramen** and runs in the **posterior part of the intercostal space** passing between the **parietal pleura** and the **posterior intercostal membrane**.
- From the angle of the rib to the **costo-chondral junction**, the nerve runs in the **costal groove** below the **intercostal vein and artery (VAN)** passing between the **innermost intercostal muscle** and the **internal intercostal muscle**.

Branches of a typical intercostal nerve

1. **Rami communicantes:**

- the intercostal nerve gives a **white ramus communicans** (**preganglionic**) to sympathetic trunk & receives a **grey ramus communicans** (**postganglionic**) from the sympathetic trunk.
- **The gray ramus** joins the nerve medial at the point at which the white ramus leaves it.

Note:

- Grey rami communicantes are present in all spinal nerves while the white rami communicantes are present only in the thoracic and upper 2-3 lumbar nerves.

2. Muscular branches:

- to the intercostal muscles and transversus thoracis.

3. A collateral branch:

- runs along the upper border of the rib below.

4. Pleural sensory branches

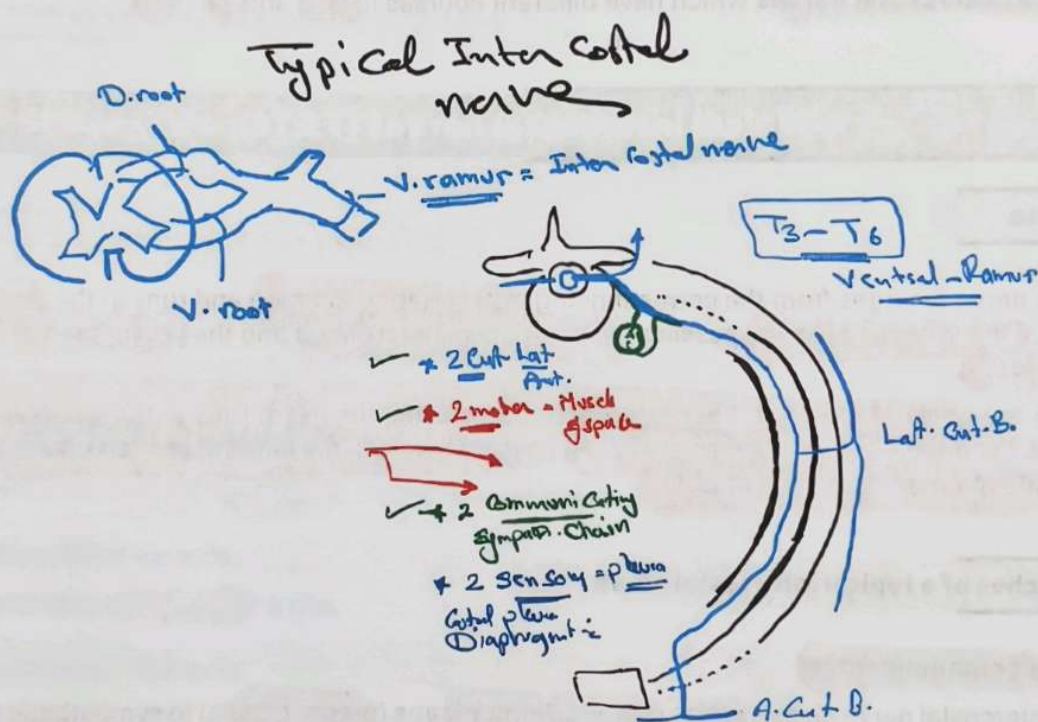
- go to the parietal pleura.

5. Lateral cutaneous branch:

- pierces the intercostal muscles and digitations of serratus anterior and emerges on the lateral side of the trunk dividing into an anterior and a posterior branch to supply the skin.

6. Anterior cutaneous branch:

- the terminal branch that appears near the sternum and divides into medial and lateral branches which supply the overlying skin.



2. Atypical intercostal nerves:

1. First intercostal nerve (T1):

- It divides unequally into a large branch that ascends across the neck of the 1st rib to share in the brachial plexus.
- The smaller 1st intercostal nerve runs in the 1st intercostal space and ends as the 1st anterior cutaneous nerve of the thorax.
- It gives no lateral cutaneous branch.

2. Second intercostal nerve (T2):

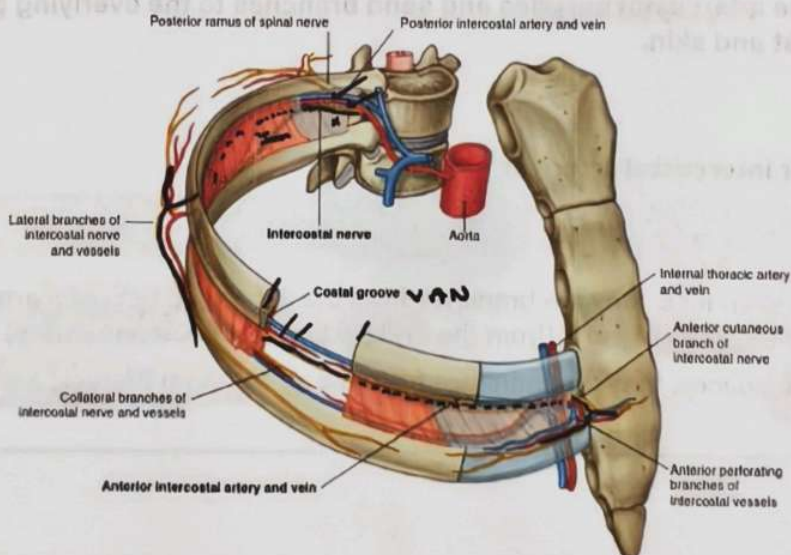
- Its lateral cutaneous branch is known as intercostobrachial nerve, which runs in the axilla communicating with the medial cutaneous nerve of the arm and supplies the skin of the floor of axilla and upper part of the medial side of the arm.

3. Lower 5 intercostal nerves (T1-T11):

- They pass between the costal slips of diaphragm to the anterior abdominal wall to supply muscles and skin.
- They also supply the parietal peritoneum.

Note:

- The ventral ramus of T12 (subcostal) nerve also supplies the muscles and the skin of the anterior abdominal wall.

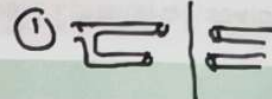


Arteries of the Thoracic Wall

i. The intercostal arteries:

- The intercostal arteries course through the thoracic wall between the ribs.
- With the exception of the 10th and 11th intercostal spaces, each intercostal space is supplied by:

1 A large posterior intercostal artery and its collateral branch.



2 A small pair of anterior intercostal arteries.



1. The anterior intercostal arteries:

They are 9 pairs for the upper 9 intercostal spaces.

- In the upper 6 intercostal spaces, they are branches from the internal thoracic artery.

In 7th 8th and 9th intercostal spaces

- they are branches from the musculophrenic artery which is one of the terminal branches of the internal thoracic artery.

The 10th and 11th intercostal spaces

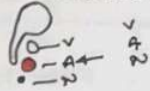
- have NO anterior intercostal arteries because they are incomplete anteriorly.
- In each space the 2 anterior intercostal arteries start from the anterior end of the space, run laterally then terminate at the costo-chondral junction by anastomosing with the posterior intercostal artery and its collateral branch of the same space.
- They supply the intercostal muscles and send branches to the overlying pectoral muscles, breast and skin.

2. The posterior intercostal arteries:

Origin:

- In the 1st and 2nd spaces, they are branches from the superior intercostal artery which is a branch of the costocervical trunk (from the 2nd part of the subclavian artery).
- In the 3rd to 11th spaces, they are branches from the descending thoracic aorta.

**Course:**

- Each artery lies at first between the pleura and internal intercostal membrane as far as the costal angle, then passes between the internal intercostal and innermost intercostal muscles (at the neurovascular plane).
- In the costal groove** it runs below its vein and above the intercostal nerve (VA) 
- At the angle of the rib**, it gives a collateral branch which runs along the upper border of the rib below.
- At the costo-chondral junction**, the posterior intercostal artery and its collateral branch end by anastomosing with the anterior intercostal branches from the internal thoracic or musculophrenic artery.

Note:

- The **10th and 11th** posterior intercostal arteries terminate in the muscles of the **abdominal wall** due to the absence of 10th and 11th anterior intercostal arteries.



ii. Internal thoracic artery

Origin:

- From the **1st part of the subclavian** artery in the root of the neck.

Course:

- It descends vertically behind the upper 6 costal cartilages one cm from the lateral border of the sternum.

Termination:

- In the **6th intercostal space**, it divides into **musculophrenic** and **superior epigastric** arteries.

Branches:

- 1. Pericardiophrenic artery:**
 - a long slender branch accompanying the **phrenic nerve** to the **diaphragm** supplying twigs to **pericardium**, **pleura** and **diaphragm**.
- 2. Pericardial branches.**
- 3. Anterior intercostal branches:**
 - two arteries for the upper **6** intercostal spaces.
- 4. Perforating branches:**
 - accompany the anterior cutaneous nerves
 - The perforating branches of the **2nd**, **3rd** and **4th** intercostal spaces supply the **mammary gland** in female and enlarge during lactation.
- 5. Musculophrenic artery:**

one of the 2 terminal branches.

 - It passes in ferolaterally behind the **7th** to **9th** costal cartilages.
 - It **traverses the diaphragm** to supply it and the **abdominal muscles**.
 - It gives **2 anterior** intercostal arteries for each of **7th**, **8th** and **9th** intercostal spaces.
- 6. Superior epigastric artery:**

is the 2nd terminal branch of the internal thoracic a.

 - It descends between the **costal** & **sternal** origin of the **diaphragm** to enter the **rectus sheath**.
 - It supplies the rectus abdominis and anastomoses with the inferior epigastric artery.
 - It also supplies the abdominal skin and the diaphragm.

i. intercostal veins:

1. Anterior intercostal veins:

- Each of the upper 9 intercostal spaces is drained by 2 anterior intercostal veins.

| Veins of the 7th, 8th and 9th spaces

- are drained into the venae comitantes of the **musculophrenic** artery

| Those of the 6th, 5th, 4th, 3rd spaces

- are drained into the venae comitantes of the **internal thoracic** artery which unite to form the **internal thoracic vein** at the level of the 3rd costal cartilage.

The anterior intercostal veins of the **upper 2 spaces** drain directly into the **internal thoracic vein** which drains into the brachiocephalic vein.

2. Posterior intercostal veins:

- They are **11 pairs**; each runs posteriorly in the **costal groove above its artery (VAN)**.
- They have different arrangement and mode of drainage on both sides.

a- On the right side:

| The 1st right posterior intercostal vein

- ends in the **right brachiocephalic vein**.

| The 2nd and 3rd right posterior intercostal veins

- unite to form **right superior intercostal** vein which ends in the **arch of azygos vein**.

| The posterior intercostal veins from the 4th - 11th space

- ends **separately** in the **azygos vein**.

b- On the left side:

| The 1st left posterior intercostal vein

- ends in the **left brachiocephalic vein**.

The 2nd and 3rd left posterior intercostal veins

- unite to form **left superior intercostal vein** which ends in the **left brachiocephalic vein**.

The posterior intercostal veins from 4th to 8th space

- ends separately in the **accessory (superior) hemiazygos vein** which descends then turns to the right crossing the body of the **7th thoracic vertebra to join** the vena azygos.

The posterior intercostal veins from 9th to 11th space

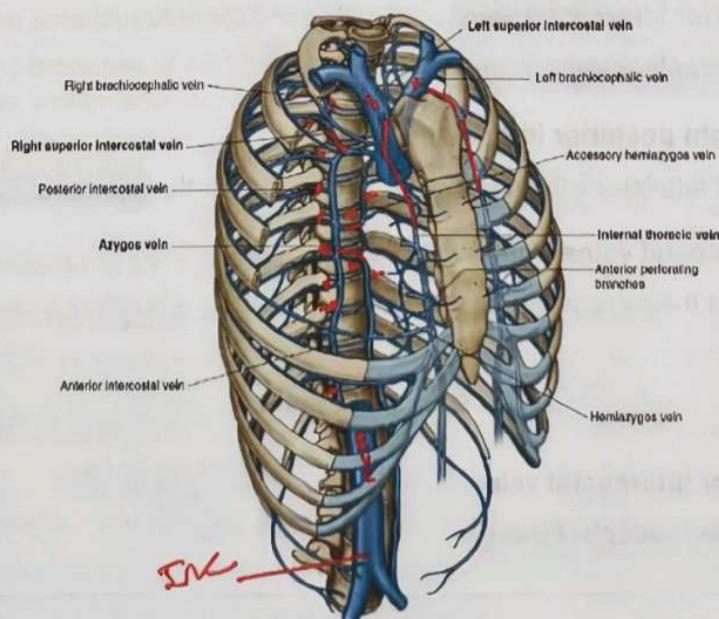
- ends separately in the **hemiazygos (inferior hemiazygos) vein** which arises from the back of the left renal vein, pierces the left crus of diaphragm to enter the thorax then crosses the body of the **8th thoracic vertebra to join** the azygos vein.

Note:

- The **accessory hemiazygos** and **hemiazygos** veins may be together by **venous loop** before crossing to the right side.

ii. Internal thoracic vein:

- The **venae comitantes** of the **superior epigastric** and **musculophrenic** arteries unite at the **anterior end of 6th intercostal space** to form the **venae comitantes** of the **internal thoracic artery**.
- On each side, the **2 venae comitantes** of the **internal thoracic artery** unite at the **3rd costal cartilage** to form a **single internal thoracic vein** which ends in the corresponding **brachiocephalic vein**.





Diaphragm

- The diaphragm is a musculofibrous sheet that separates the thoracic cavity from the abdominal cavity.
- Its convex upper surface facing the thoracic cavity and its concave inferior (lower) surface is directed towards the abdominal cavity.
- The central part of the diaphragm is depressed inferiorly than the lateral parts which are called cupolae

Origin

- The muscle fibres of the diaphragm arise from the oblique circumference of the thoracic outlet.
- Although it is a continuous sheet, the diaphragm can be considered to be formed of three parts; sternal, costal and lumbar (vertebral).

The sternal part:

- arises by 2 fleshy slips from the back of the xiphoid process.

The costal part:

- arises from the internal surfaces of the lower 6 costal cartilages and their adjoining ribs.

The lumbar (vertebral) part:

- arises from lumbar vertebrae by 2 crura (right crus and left crus) and by 2 aponeurotic arches, the medial and lateral arcuate ligaments on each side.

The **Crura** are thick fleshy bundles that taper inferiorly:

The right crus:

- is broader and longer than the left. It arises from the anterolateral surfaces of the bodies of the upper 3 lumbar vertebrae and intervertebral discs.

The left crus:

- arises from the anterolateral surfaces of the upper 2 lumbar vertebrae and intervertebral disc.

Note:

- Medial fibres of the right crus embrace the oesophagus where it passes through the diaphragm.

The arcuate ligaments:**The median arcuate ligament:**

- is an arch in the **midline** across the **front of the aorta** at the level of the **disc between T12 and L1 vertebrae** connecting the medial tendinous margins of the crura.

The medial arcuate ligament:

is a tendinous arch in the fascia that covers the upper part of **psoas major**.

- Medially**, It is continuous with the lateral margin of the **corresponding crus**, so it is attached to the side of the body of L1 or L2 vertebra.
- Laterally**, it is attached to the **front of the transverse process of L1 vertebra**. *MC*

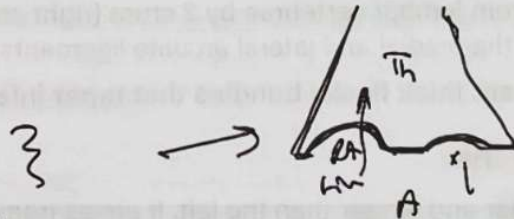
The lateral arcuate ligament:

a thickened band of fascia that arches across Upper part of **quadratus lumborum** muscle.

- Medially** attached to the **front of the transverse process of L1 vertebra**
- Laterally** attached to lower margin of the **12th rib near its midpoint**.

The central tendon of the diaphragm

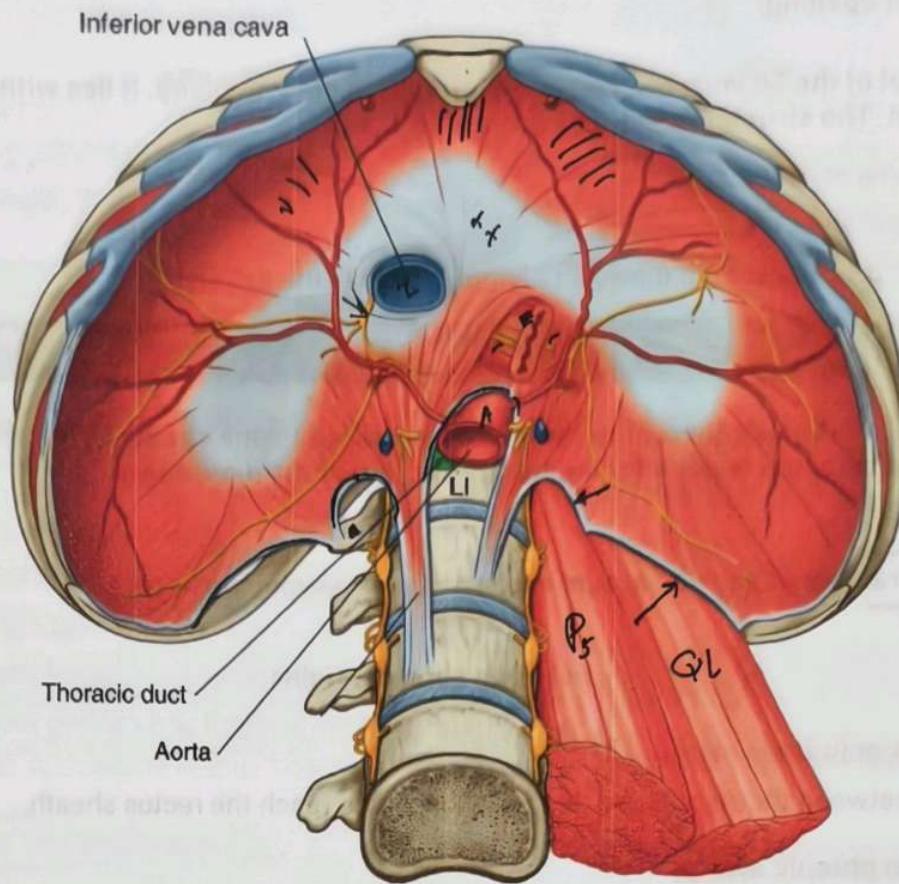
- The fibers of origin of diaphragm converge to be inserted into a strong aponeurotic tendon called the central tendon.
- It is semi lunar in shape and divided by slight indentations into 3 leaflets: 1 middle & 2 lateral.

Relations of The diaphragm**Superiorly the diaphragm is related to:**

- The right cupola** is related to the right pleura and base of the right lung.
- The left cupola** is related to the left pleura and base of the left lung.
- The median part** of the central tendon is related to the pericardium and the heart.

Inferiorly the diaphragm is related to:

- The right cupola** is related to the right lobe of the liver, right kidney and right supra renal gland.
- The left cupola** is related to the left lobe of the liver, fundus of the stomach, left kidney, left suprarenal gland and spleen.
- The right cupola** reaches at a **slightly higher level than the left cupola** due to upward bulge of right lobe of the liver.



Major openings in The diaphragm

a- Aortic opening:

It is at the level of the lower border of the **T12** vertebra, nearly in the **median** plane posterior to the median arcuate ligament. the structures passing through are:

- 1. **Aorta** (descending).
- 2. **Thoracic duct**.
- 3. **Azygos vein**.

b- Oesophageal opening:

It is at the level of the **T10** vertebra **one inch to the left of the median** plane, within the **fleshy fibres of the right crus** which have a **sphincteric** action on the lower end of the oesophagus. the structures passing through are:

- 1. **Oesophagus**.
- 2. **Gastric nerves** (anterior and posterior).
- 3. **Oesophageal branches of the left gastric vessels**.



c- Vena caval opening:

It is at the level of the **T8 vertebra one inch right to the median plane**. It lies within the **central tendon**. The structures passing through are:

- 1. Inferior vena cava (I.V.C)
- 2. Branches of the right phrenic nerve.
- 3. Some lymph vessels from the liver to lymph nodes of the thorax.

Note:

- The central tendon is adherent to the wall of the inferior vena cava thus keeping it always patent and its lumen is not affected by contraction of the diaphragm.

Minor foramina of The diaphragm and structures passing through

a- Between slips of origin:

1. Superior epigastric artery:

- passes between the **sternal** and the **costal** origins to reach the rectus sheath.

2. Musculo phrenic artery:

- pierces the diaphragm near the **9th costal cartilage**

3. Lower 5 intercostal nerves:

- each passes between 2 slips of costal origin reach the anterior abdominal wall.

b- Behind the lateral arcuate ligament:

- 1. Subcostal vessels and nerve.
- 2. Quadratus lumborum muscle.

c- Behind the medial arcuate ligament:

- 1. Sympathetic trunk: continues from thoracic cavity to abdominal cavity.
- 2. Psoas major muscle.

d- Through minute openings in the crura:

- 1. Greater and lesser splanchnic nerves via 2 openings in each crus.
- 2. Hemiazygos vein: pierces the **left crus** of diaphragm to enter the thoracic cavity.

Note:

- The left phrenic nerve passes through the muscular part of the diaphragm anterolateral to the left part of the central tendon.

Nerve supply of The diaphragm**Motor supply:**

- Right and left phrenic nerves (C 3, 4, 5 mainly C4).
- These nerves pierce the diaphragm to supply it from its inferior surface.

Sensory supply:

- branches from phrenic and lower intercostal nerves.

Arterial supply

- Inferior phrenic arteries.
- Musculophrenic arteries.
- Pericardiophrenic arteries.
- Twigs from lower 3 posterior intercostal arteries.
- Twigs from descending thoracic aorta.

Action of The diaphragm

It is the chief muscle of respiration.

- It is active during forced expulsive acts, e.g. coughing, vomiting, defecation, urination and parturition.



Movements of Respiration:

Respiration consists of two phases; inspiration and expiration during which an increase and a decrease of the capacity of the thoracic cavity occur respectively.

1. Inspiration:

The diaphragm is the major muscle of inspiration.

In Quiet inspiration: all the diameters of the thoracic cavity will increase

Vertical diameter

- is increased by contraction (descent) of the diaphragm.

Anteroposterior diameter

- is increased by contraction of intercostal muscles which raise the sternal ends of the downward-sloping ribs. Also the sternum will be pushed upward and forward increasing this diameter (pump-handle movement).

Transverse diameter

- Is increased by contraction of the intercostal muscles which elevate the middle of the shaft of the 7th and false ribs which lie in a lower level than their anterior and posterior ends (bucket-handles movement).

In forced inspiration:

There is a maximum increase in the capacity of the thoracic cavity. Every muscle that can raise the ribs is brought into action e.g.:

- **Scalenus anterior and medius** elevate the first rib.
- **Sternocleidomastoid** acts directly through the manubrium sterni and indirectly through the clavicle.
- The scapulae are fixed by the trapezius, levator scapulae and rhomboid muscles which enable the **serratus anterior** and pectoralis minor to pull up the ribs.
- **Quadratus lumborum** fixes the 12th rib so that the diaphragm can exert a more powerful downward push on the abdominal viscera.

2. Expiration:

Quiet expiration is passive & achieved by:

- Elastic recoil of the lungs.
- Relaxation of the intercostal muscles and diaphragm.

Forced expiration:

- It is an active process during which the **muscles of the anterior abdominal wall** and **latissimus dorsi** contract strongly pushing the diaphragm upwards and drawing the lower ribs downwards and inwards.

